Katarzyna Knoll*
UNIVERSITY OF SILESIA IN KATOWICE

Dùzi bǎole or *tùzi pǎole*?
The perception of Mandarin word-initial stops by Poles

Abstract: This paper concentrates on the perception of voicing contrasts in Mandarin Chinese stops by Polish speakers: advanced adult learners of Mandarin, and adults and children who have no knowledge of this Asian language. The results indicate that short-lag stops (0–20 ms VOT) pose a difficulty for Poles, and that the perception of voicing contrasts is both age- and experience-dependent. Advanced learners consistently divide stops into lenis (/p t k/) and fortis (/p^h t^h k^h/), and identification of the place of articulation of a given stop is relatively easy for them. Adults who do not know Mandarin, on the other hand, do not have such a strong categorisation effect, their voicing judgments are more ambiguous, and making distinction between labials, denti-alveolars and velars appears to be more difficult for them. Recognition of stops is also difficult for the youngest Poles, who tend to identify lenis /p t k/ and fortis /p^h t^h k^h/ as belonging to the same, fortis, category.

Key words: Voice Onset Time (VOT), perception, Mandarin stops, voicing contrasts

1. Introduction

Voice Onset Time has been widely used as one of the most reliable acoustic features for investigating voicing contrasts in stops, and it has been applied in the studies of many languages. A number of such studies have shown that Polish divides up the VOT continuum with two categories: voicing lead vs. short lag, whereas Mandarin generally contrasts short lag vs. long

* Katarzyna Knoll is a Chinese language teacher at the University of Silesia, Poland. After graduating from the university in 2015, she became a PhD student in the field of linguistics at the University of Silesia. Her primary area of research is foreign language acquisition, and she is particularly interested in the acquisition of the phonetic systems of a second and third language (i.e. English and Chinese).

lag. However, to the best of our knowledge, there are no studies investigating the perception of voicing contrast in Mandarin by native speakers of Polish.

Thus, in the present study we make an attempt to answer the question of how Poles perceive voicing contrasts in Mandarin and, most importantly, how this perception develops along with language experience and/or age.

2. Voice Onset Time

Introduced by Lisker and Abramson in 1964, the Voice Onset Time (VOT) is "the time interval between the burst that marks release and the onset of periodicity that reflects laryngeal vibration" (Lisker and Abramson 1964: 422). In other words, it can be defined as the time between the burst of air and the initiation of a vowel.

In most languages, stops can be characterized as produced with (i) voicing lead, (ii) short voicing lag, or (iii) long voicing lag.

(i) Voicing lead (negative VOT): voicing starts before the release of the stop, (approximately –30 ms or more VOT).

(ii) Short voicing lag (zero onset): voicing begins at or just after the release of the plosive (approximately 0 to +30 ms or up to +35 ms (Keating 1984).

(iii) Long voicing lag (positive VOT): voicing begins well after the release of the stop (approximately +50 ms or more VOT). It is either accompanied by silence (Klatt 1975) or aspiration which is heard "if the vocal tract resonates to turbulent air passing through the open glottis" (Lisker and Abramson 1964: 416).

3. VOT values for Mandarin and Polish stops

Mandarin and Polish exploit the VOT continuum differently. It is well known that Mandarin has no phonetically voiced stops, and it is aspiration that is the only distinctive phonetic feature differentiating voiceless unaspirated and voiceless aspirated stops. Polish, on the other hand, "contrasts prevoiced stops with voiceless unaspirated or slightly aspirated stops, which corresponds to a contrast of voicing lead with short-lag VOT" (Keating *et al.* 1981: 1261).

In Table 1, measurements of Polish VOT means, as reported in Kopczyński (1977) and Keating *et al.* (1981), are presented, whereas Table 2 presents measurements of Chinese VOT means, as reported by different scholars: Shi and Liao (1986), Wu (2004), Rochet and Fei (1991), Ran (2005), Chao *et al.* (2006), and Chao and Chen (2008).

Table 1. Mean VOT values for Polish stops; all measurements in milliseconds

Measurements for stops reported by	p^h	t^h	k^h	p	t	k	b	d	g
Kopczyński				+37.5	+33	+49	–78	–72	–61
Keating *et al.*				+21.5	+27.9	+52.7	–88.2	–89.9	–66.1

Table 2. Mean VOT values for Mandarin Chinese stops: DS = disyllables; all measurements in milliseconds

Measurements for stops reported by	p^h	t^h	k^h	p	t	k	b	d	g
Shi and Liao	+94	+100	+103	+7	+7	+18			
Wu	+72	+100	+85	+7	+9	+19			
Rochet and Fei	+99.6	+98.7	+110.3						
Ran	+106	+104	+112	+12	+13	+30			
Chao *et al.* DS	+82	+81	+92	+14	+16	+27			
Chao and Chen DS	+77.8	+75.5	+85.7	+13.9	+15.3	+27.4			

As can be seen, Polish voiceless stops are produced with moderate positive VOT values, slightly higher than mean VOTs for Mandarin voiceless unaspirated stops, but also much lower than VOT values for Mandarin voiceless aspirated stops.

4. Description of the research

4.1. Objectives

This paper presents a part of a study described in the author's unpublished MA thesis (Knoll 2015). The study concentrated on the perception of Mandarin, English and Polish word-initial stops by Polish speakers (see also Knoll 2015). The present paper can be viewed as an attempt to show how Polish speakers perceive voicing contrasts in Mandarin, and how this perception develops along with language experience and/or age.

As it is the perception of voicing contrasts, which is our primary concern (i.e. phonological rather than phonetic aspects), for the purposes of the present study, we will abandon using 'voiced/voiceless' in favour of 'fortis/lenis.'

4.2. Subjects

A total of 60 subjects participated in the study. All the subjects volunteered and were not paid for their participation. None of the participants reported any speech or hearing disorders. They were all naive to the object of the study.

The subjects were divided into three groups: (i) children, (ii) adults, (iii) adults: advanced learners of Mandarin.

(i) Children: The group comprised 20 Polish children at the age of 8: 10 males and 10 females. They were recruited from the first-year pupils at Stefan Żeromski Primary School no. 53 in Katowice. They had no experience in learning Mandarin Chinese.

(ii) Adults: A total of 20 Poles participated in the study: 10 males and 10 females. They were all fourth- and fifth-year students of non-philological fields of study and had no sophisticated knowledge in linguistics. They had never had any experience with learning Mandarin Chinese. The participants ranged in age from 23 to 26 (Mean = 23.4, Std. Dev. = 0.94).

(iii) Adults: Advanced Learners of Mandarin. A total of 20 Polish Advanced Learners of Mandarin participated in the study: 4 males and 16 females. They were all fifth-year students of English Philology following the English-Chinese translation programme of studies at the University of Silesia, Poland. Their skills in Mandarin had been repeatedly confirmed by annual practical examinations. They ranged in age from 22 to 25 years (Mean = 22.6, Std. Dev. = 0.75). They had four years of experience in learning Mandarin Chinese.

4.3. Stimuli

We selected six Mandarin syllables whose onsets (声母 *shēng mǔ* 'initials') were /p p^h t t^h k k^h/. Since common words can be both produced (e.g. Dell 1990) and recognised (e.g. Oldfield and Wingfield 1965) with greater facility than rare words, we selected such items that were not similar to any Polish real-words, so as to avoid lexical influence, especially in the case of subjects with no knowledge of Mandarin. CV(V) and CVC patterns were used, i.e. each item had three sounds: (i) a stop consonant, (ii) a vowel (the low vowel /a/ or mid-low vowel /æ/), (iii) a consonant or another vowel (i.e. second part in a diphthong).

The stimuli used in the experiment were recordings of the selected lexical items. We used recordings from popular course books and textbooks, so as

to make sure that the speakers' pronunciation could be considered to be standard Mandarin pronunciation. The items were all produced by male speakers. Two stimuli were produced in high-level (HL) tone, one in mid-rising (MR), two in falling-rising (FR), and one in high-falling (HF) tone. Then, VOT values of word-initial stops in each stimuli were measured using Praat 5.4.06 speech-analysis software package (Boersma and Weenink 2015) by means of a spectrographic display and waveforms. VOT in each stimulus was measured between the first peak of the release burst to the onset of the second formant of the following vowel (e.g. Keating *et al.* 1981).

The following items were given to the subjects:

(1) 排 *pái* 'a row': /pʰaɪ/, /pʰ/ +166 ms VOT
(2) 百 *bǎi* 'a hundred': /paɪ/, /p/ +10 ms VOT
(3) 毯 *tǎn* 'a blanket': /tʰan/, /tʰ/ +118 ms VOT
(4) 单 *dān* 'a bill': /tan/, /t/ 0 ms VOT
(5) 看 *kàn* 'to look': /kʰan/, /kʰ/ +155 ms VOT
(6) 干 *gān* 'dry': /kan/, /k/ +20 ms VOT

4.4. Experimental procedures

The experiment took place in a quiet room. Prior to the experiment, each subject was instructed in Polish about the methodology of the study. We asked children if they recognised the letters on the answer sheet and they were encouraged to read out loud each consonant, that is, P, B, T, D, K, G, H, written in upper case because of the fact that children become familiar with them before they learn letters written in lower case.

Then, the subjects were asked to circle the word-initial sound they heard in each syllable. An example, that is, a Polish word *lala* (/lala/, 'a doll'), was provided for all subjects, so as to make sure that they understood the instruction. Originally, they were to choose among P, B, T, D, K, G. However, a preliminary study conducted on eight subjects (five seven-year-old children and three adults) revealed that lack of 'H' on the answer sheet leads to such confusion among five subjects (four children and one adult) that the experiment could not be continued as expected.

The stimuli were presented via high-quality headphones built in the headset at a comfortable listening level. Special care was taken to provide the same acoustics for all the subjects. Each stimulus was presented once and each presentation was followed by a three-second pause.

4.5. Measurements

For testing the significance of the between-group effect, we used a *Chi*-square test, whereas Cochran Q test was used for testing significance of the within-group effect. All statistical analyses and graphical representations were made using MS EXCEL and STATISTICA v.10.

5. Results

5.1. Overall results

The results show that fortis stops were identified as fortis in 178 instances, i.e. 98.9%, and /b d g/ were recognised as lenis in 111 instances, that is, 61.7% (Figure 1).

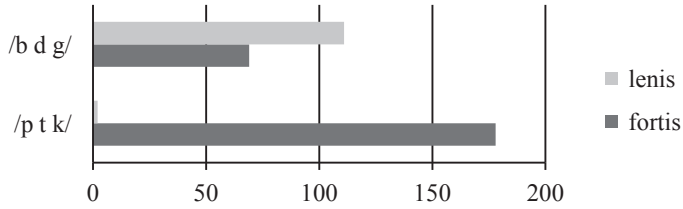

Figure 1. Perception of Mandarin stops (overall results)

5.2. Lenis stops

Children recognised /p t k/ as lenis 16 times (26.7%), whereas /b d g/ were perceived as lenis in 38 instances (63.3%). In the group of advanced learners of Mandarin, they were perceived as lenis in as many as 59 out of 60 instances (98.3%) (Figure 2). The difference in the perception of /b d g/ between the three groups was statistically significant (*Chi*-square = 71.492; p = 0.000).

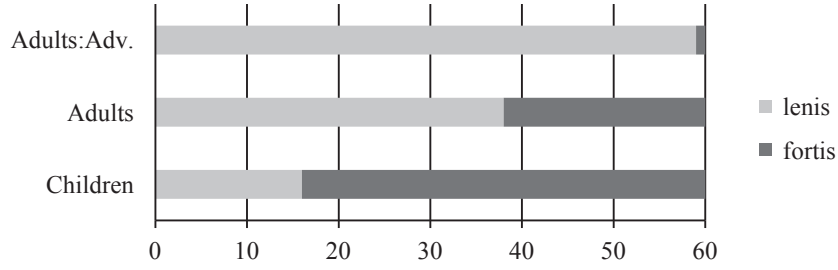

Figure 2. Recognition of Mandarin lenis stops in three groups

As shown in Figure 3, the group of advanced learners of Mandarin showed almost no within-group variance in the perception of lenis stops, and 19 out of 20 subjects perceived all three stops as lenis. The mean number of lenis stops perceived as lenis was 2.95 (Std. Dev. = 0.22). In the group of adults with no knowledge of Mandarin, less than a half of the group (seven subjects) perceived all lenis stops as lenis. The mean number of lenis stops perceived as lenis was 1.9 (Std. Dev. = 1.02). In the group of children, none of the subjects perceived all lenis stops as lenis, however, eight subjects perceived them all as fortis. The mean number of lenis stops perceived as lenis was 0.8 (Std. Dev. = 0.76).

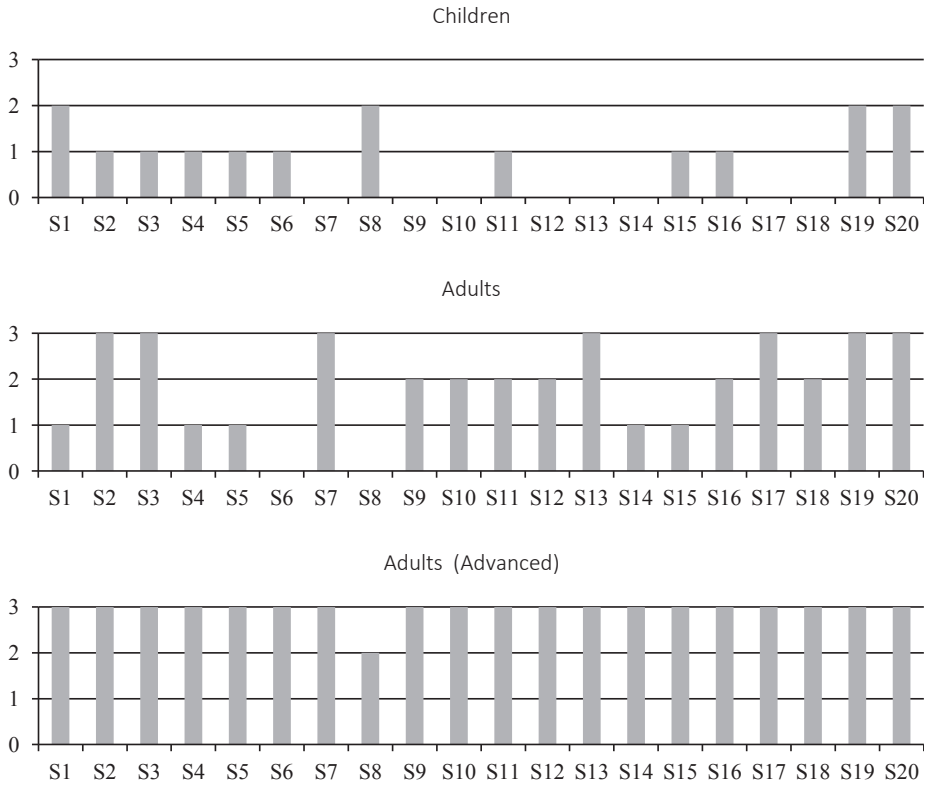

Figure 3. The number of Mandarin /b d g/ perceived as lenis by each subject

5.3. Bilabial stops

The results show that /p/ was perceived as fortis by 59 participants (98.3%). The views on whether /b/ was lenis or fortis, however, were divided, and it was labelled as lenis by 38 subjects (63.3%) (Figure 4).

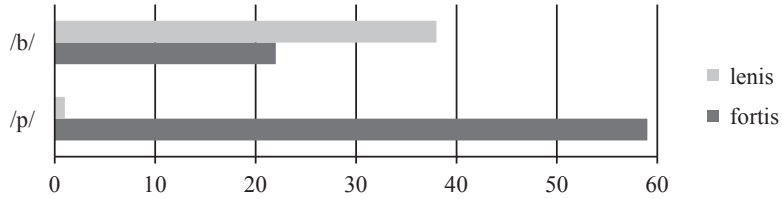

Figure 4. Perception of bilabial stops (overall results)

Between-group analysis showed that none of the advanced users of Mandarin labelled /p/ as fortis, whereas its counterpart was unanimously perceived as lenis.

In the group of adults with no knowledge of Mandarin, /p/ appeared to be more problematic, and although there was general agreement that it was fortis, four subjects labelled it as /h/, two as /t/ and one as /k/. Its lenis counterpart, /b/, was labelled as lenis by 11 subjects.

In the group of children, 13 subjects labelled /b/ as fortis and seven as lenis. What is more, the highly aspirated /p/ appeared to be difficult to recognise, although 19 subjects agreed that it was fortis. Less than a half of the subjects (nine children) labelled it correctly, two subjects judged it as /k/ and eight subjects appeared to perceive only its aspiration, hence marked it as /h/ (Figure 5a, b).

Statistical analysis showed that there were significant between-group differences in the perception of lenis /p/ (*Chi*-square = 19.091; p = .000), including differences between the two groups of adults (*Chi*-square = 11.613; p = .001).

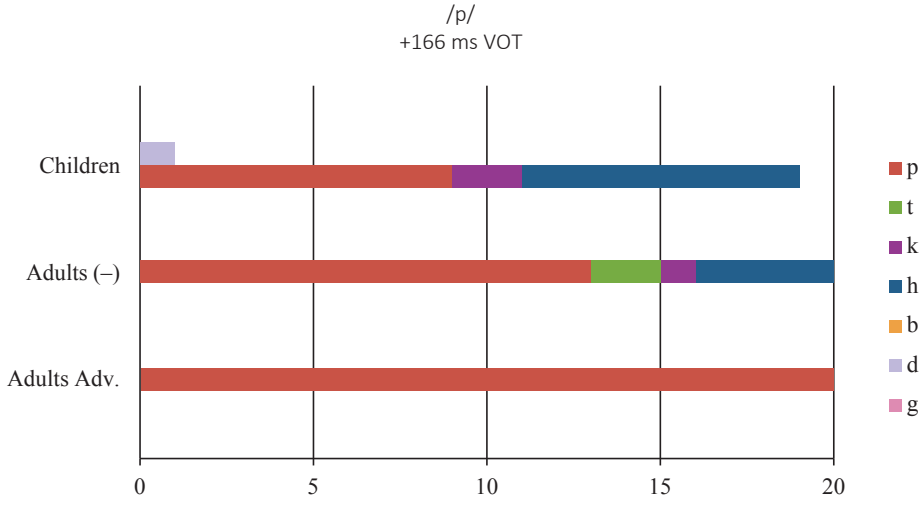

Figure 5a. Perception of /p/ and /b/ in three groups

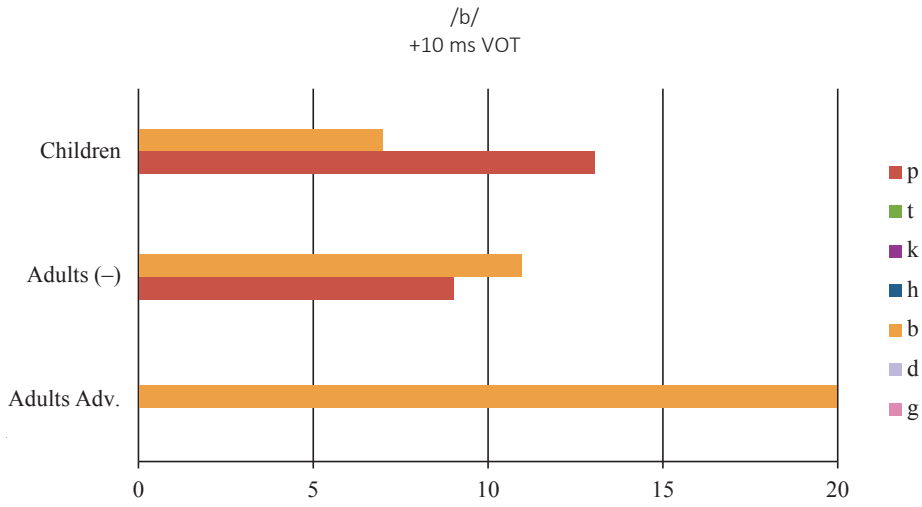

Figure 5b. Perception of /p/ and /b/ in three groups

5.4. Apical stops

Nearly all the subjects labelled /t/ as fortis (59 subjects, 98.3%), whereas /d/ was identified as lenis by 41 subjects (68.3%) (Figure 6).

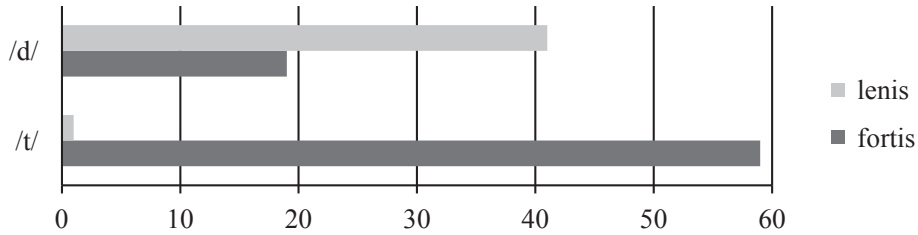

Figure 6. Perception of apical stops (overall results)

Between-group analysis showed that all of the advanced speakers of Mandarin labelled /d/ as lenis, however, some subjects failed to recognise it as an apical sound and marked it as /g/ (four subjects). All the subjects labelled /t/ as fortis, however, nearly a half of the group (eight subjects) did not manage to fully recognise that sound, and marked it as /p/.

All the adults who cannot speak Mandarin recognised /t/ as fortis, however, only three subjects identified it as an apical sound. As much as half of the group mistook it for /p/, one subject for /k/, and six labelled it as /h/. Sixteen subjects perceived /d/ as lenis: six of them labelled it as /g/, and seven subjects as /d/. The same number, that is, seven subjects, identified it as fortis /t/.

Although 19 children labelled the highly aspirated /t/ as fortis, there was only one subject who identified it as an apical. Two subjects opted for /p/, one for /k/, and as many as 15 subjects for /h/. The denti-alveolar /d/ was perceived as fortis by 12 subjects, among whom ten identified that sound correctly, that is, as a denti-alveolar stop. There were eight children who claimed that it was /d/ rather than /t/ (Figure 7a, b).

Statistically significant between-group differences were found in the perception of /d/ (*Chi*-square = 16.791; p = .000), including differences between the two groups of adults in the perception of the Mandarin /d/ (*Chi*-square = 8.485; p = .004).

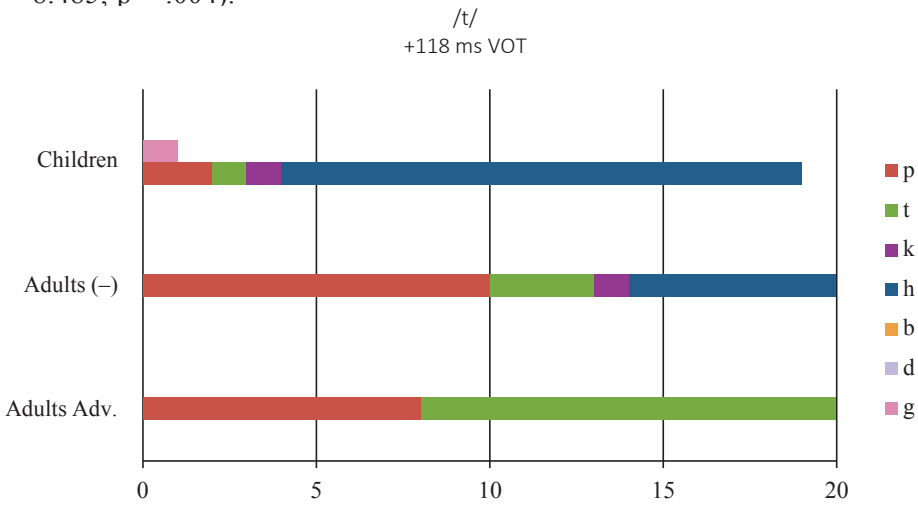

Figure 7a. Perception of /t/ and /d/ in the three groups

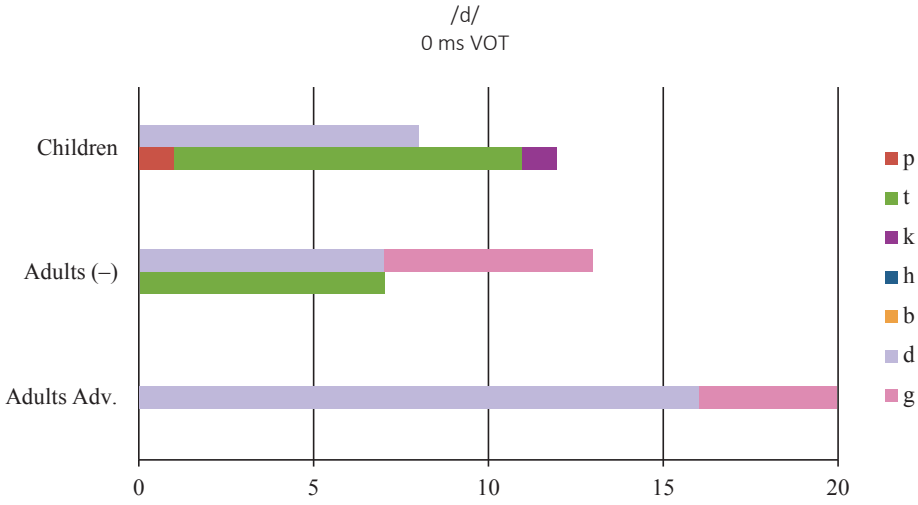

Figure 7b. Perception of /t/ and /d/ in the three groups

5.5. Velar stops

All the participants of the study perceived /k/ as fortis. Once again, however, voicing judgments were divided in the case of the lenis velar, and 35 subjects opted for its being lenis (58.3%) (Figure 8).

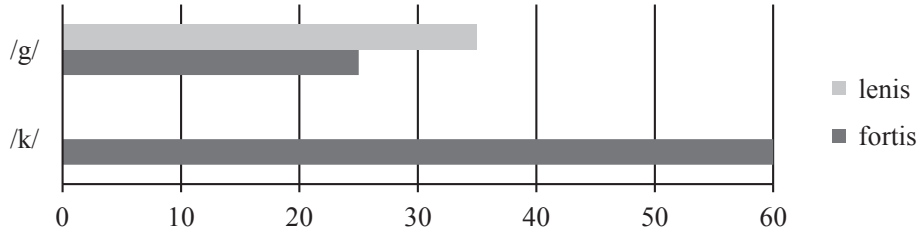

Figure 8. Perception of velar stops (overall results)

All the advanced learners identified /k/ as fortis, however, four speakers failed to recognise it as a velar sound: one labelled it as /p/, one as /t/, and two as /h/. There were 19 subjects who identified the lenis velar stop as /g/, and only one who recognised it as fortis. In the group of adults without knowledge of Mandarin, 15 subjects labelled /k/ as fortis /k/, whereas /g/ was perceived as a lenis stop by 14 subjects. In the group of children, /k/ was unanimously recognised as fortis, however, none of the participants labelled it as a velar: two marked it as /p/ and as many as 18 children as /h/. There was general agreement among the subjects that the fortis velar was fortis (16 subjects marked it as /k/ and two as /t/) (Figure 9a, b). Statistical analysis showed significant between-group differences in the perception of /g/ (*Chi*-square = 31.406; p = .000), including:

(1) differences between the two groups of adults (*Chi*-square = 4.329; p = .037);

(2) differences between the children and adults with no knowledge of Mandarin (*Chi*-square = 15.000; p = .000).

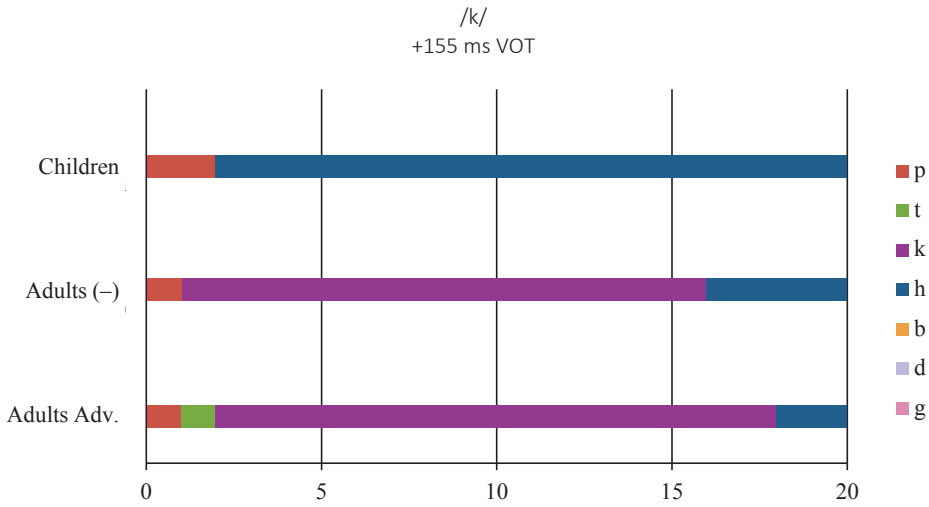

Figure 9a. Perception of /k/ in three groups

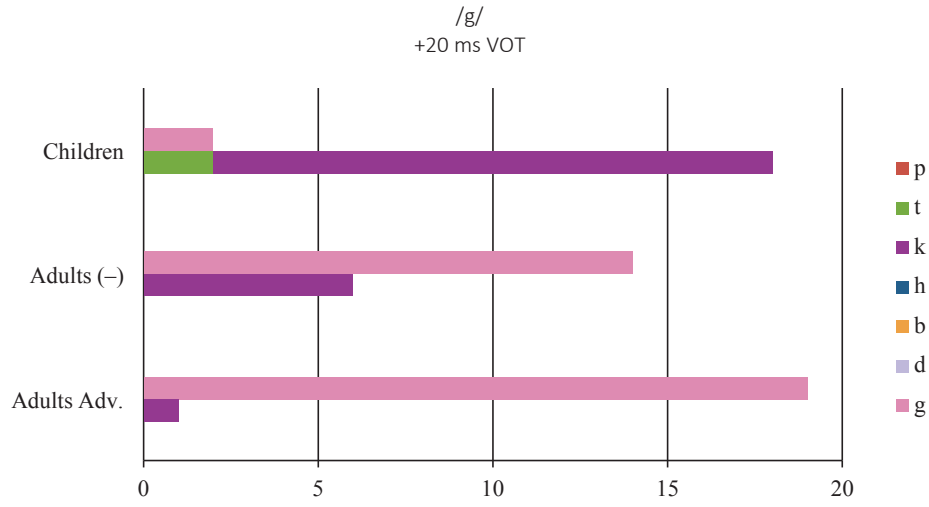

Figure 9b. Perception of /g/ in three groups

6. Discussion

In the group of advanced learners, /b d g/ were generally perceived as lenis, that is, they were perceived as lenis 98.3% of the time, and 95% of the subjects labelled all three sounds as such. As shown in Figure 10, the recognition of each stop ranging between 0 and 20 ms as lenis was very high (95–100%). As shown in Figure 11, adults who do not speak Mandarin, however, perceived /b d g/ as lenis 73.3% of the time, with the highest lenis judgements

for the +20 ms VOT /g/ (70%) and the lowest for +10 ms VOT /b/ (55%). As indicated in Table 3, the difference between the two groups in the perception of short-lag stops was found to be statistically significant (*Chi*-square = 23.720; p = 0.000), and further analysis showed that there were significant differences in the perception of +10 ms /b/ and +20 ms /g/.

Table 3. Differences in the perception of lenis stops between the two groups of adults (p-values)

0 ms	+10 ms	+15 ms	+20 ms
p = 0.113	**p = 0.001**	–	**p = 0.037**

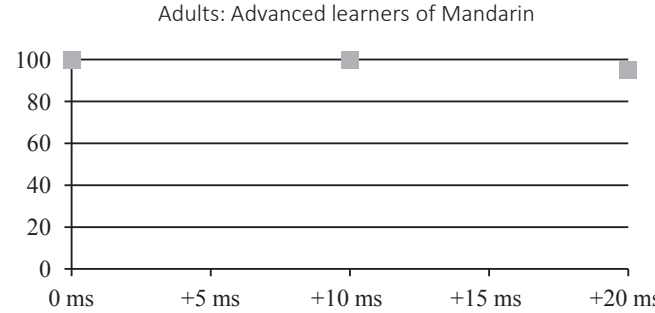

Figure 10. Recognition of lenis sounds as lenis across the VOT continuum [in percentage]

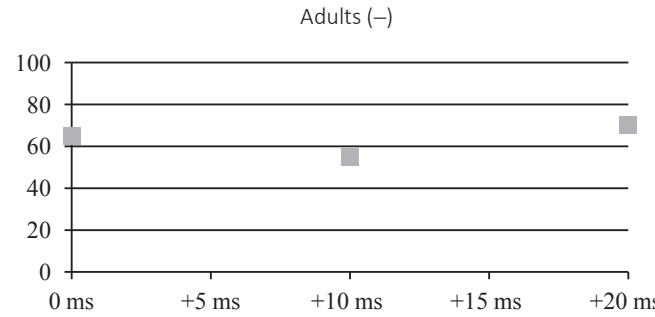

Figure 11. Recognition of lenis sounds as lenis across the VOT continuum [in percentage]

It can be seen that the advanced learners had a strong categorisation effect along the VOT continuum as all the values between 0 and +20 ms VOT were consistently categorised as lenis (mean number lenis stops recognised as lenis was 5.85, Std. Dev. = 0.49). In the group of adults with no knowledge of Mandarin, lenis stops were less frequently recognised as lenis: there were seven subjects who recognised all three stops as lenis, and two who perceived them as fortis (mean = 1.9; Std. Dev. = 1.02) (Table 4).

Table 4. Mean number of lenis stops perceived as lenis

Type of Measure	Adults: Advanced learners	Adults (–)
Mean	2.95	1.9
Std. Dev.	0.22	1.02

The children categorised /b d g/ as lenis only 26.7% of the time, with the highest lenis judgements for the 0 ms VOT /d/ (40%) and the lowest for +20 ms VOT /b/ (10%) (Figure 12). The difference between the children and adults with no knowledge of Mandarin was found to be statistically significant (*Chi*-square = 16.298; p = 0.000). Further analyses showed that only differences in the perception +10 ms VOT /b/ did not meet the criteria of statistical significance (p > 0.05) (Table 5).

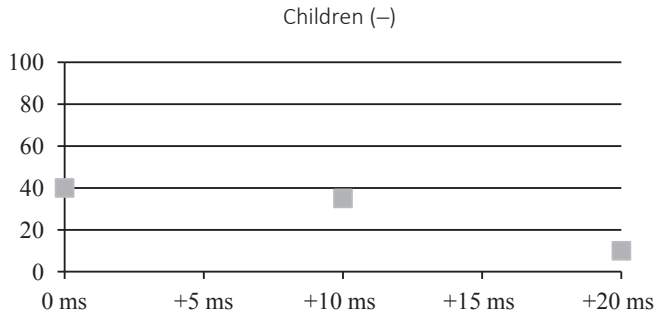

Figure 12. Recognition of lenis sounds as lenis across the VOT continuum [in percentage]

Table 5. Differences in the perception of lenis stops between children and adults with no knowledge of Mandarin (p-values)

0 ms	+10 ms	+15 ms	+20 ms
p = 0.004	p = 0.204	–	**p = 0.000**

As shown in Table 6, in the group of children, the mean number of lenis tokens perceived as lenis was almost two times lower than in the group of adults (Mean = 2.2; Std. Dev. = 1.64). None of the subjects perceived all Mandarin lenis stops as lenis, and the mean number of lenis judgements for these sounds was very low, that is, 0.8 (Std. Dev. = 0.76). Within-group analyses showed that the stimulus effect was statistically significant (Q = 7.167, p < 0.028).

Table 6. Mean number of lenis stops perceived as lenis

Type of Measure	Children (–)	Adults (–)
Mean	0.8	1.9
Std. Dev.	0.76	1.02

7. Conclusions

It has been shown that for Polish speakers, the perception of voicing contrasts in Mandarin differs with their language experience and age. The results of the study show that Polish advanced learners of Mandarin consistently divide word-initial stops into fortis and lenis: long-lag stops are categorised as belonging to fortis category, whereas short-lag stops are perceived as lenis. What is more, advanced learners can determine the place of articulation of a given stop nearly perfectly. Adults for whom Mandarin is a novelty, however, do not have such a strong categorisation effect. Not only are their voicing judgments more ambiguous, but also recognition of the place of articulation of a particular sound appears to be a more challenging task for them. It is possible to conclude that these between-group differences in the perception of stops are directly related to the differences in FL proficiency: it appears that sensitivity to Mandarin boundaries with the positive VOT values can be acquired in the process of learning, and that establishing 'lenis' category for voiceless unaspirated and 'fortis' category for voiceless aspirated stops is a part of the process of acquisition of Mandarin sounds.

The results also indicate that children who have no FL experience have a critical point at +20 ms VOT, at which we can observe almost a complete shift into the fortis category. For VOT values lower than +20 ms, there is a gradual shift into lenis category, although the number of fortis judgments is still significantly higher. Moreover, making distinction between labials, apicals and velars, especially in the case of highly aspirated stops, is a very challenging task for the youngest Poles.

The present study has only shown how Polish adults and children perceive voicing contrasts in Mandarin. In order to verify present results and find out whether (and how) the perception influences the production of stops, another study is being conducted.

References

Boersma, P. and D. Weenink. 2015. Praat: Doing phonetics by computer [Computer program]. Version 5.4.08. (24 March 2015). www.praat.org.

Chao, K.-Y. and L.-M. Chen. 2008. A cross-linguistic study of voice onset time in stop consonant productions. *Computational Linguistics and Chinese Language Processing* 13.2: 215–232.

Chao, K.-Y., G. Khattab and L.-M. Chen. 2006. Comparison of VOT patterns in Mandarin Chinese and in English. *Proceedings of the 4th Annual Hawaii International Conference on Arts and Humanities*: 840–859.

Dell, G. S. 1990. Effects of frequency and vocabulary type on phonological speech errors. *Language and Cognitive Speech Processes* 5: 313–349.

Keating, P. A. 1984. Phonetic and phonological representation of stop consonant voicing. *Language* 60: 286–319.

Keating, P. A., M. J. Mikoś and W. F. Ganong III. 1981. A cross-language study of range of voice onset time in the perception of initial stop voicing. *Journal of the Acoustical Society of America* 70: 1261–1271.

Klatt, D. H. 1975. Voice-onset time, frication, and aspiration in word-initial consonant clusters. *Journal of Speech and Hearing Research* 18: 687–703.

Knoll, K. 2015. The perception of English, Mandarin and Polish word-initial stops by Polish schoolchildren and adults. *Theoretical and Applied Linguistics* 1.3: 71–91.

Knoll, K. 2015. *The perception of English, Mandarin and Polish word-initial stops by Polish schoolchildren and adults*. Unpublished master's thesis. University of Silesia, Katowice, Poland.

Kopczyński, A. 1977. *Polish and American English consonant phonemes: A contrastive study.* Warszawa: Państwowe Wydawnictwo Naukowe.

Lisker, L. and A. S. Abramson. 1964. A cross language study of voicing in initial stops: Acoustic measurements. *Word* 20: 384–422.

Luce, P. A. and D. B. Pisoni. 1998. Recognizing spoken words: The Neighborhood Activation Model. *Ear and Hearing* 20: 19–36.

Ran, Q.-B. 2005. *Jiyu putonghua de hanyu zuse fuyin shiyanjiu* [*Experimental studies on Chinese obstruent consonants: with the emphasis on standard Chinese*]. Ph.D. Dissertation, Nankai University.

Rochet, B. L. and Y. Fei. 1991. Effect of consonant and vowel context on Mandarin Chinese VOT: Production and perception. *Canadian Acoustics* 19.4: 105–106.

Shi, F. and R.-R. Liao. 1986. Zhongmei xuesheng hanyu seyin shizhi duibi fenxi [Contrastive analysis of the length of stops in Mandarin between Chinese and American students]. *Language Teaching and Linguistic Studies* 4: 67–83.

Wu, Z.-J. 2004. Putonghua fuyin busongqi/songqi qubie de shiyan yanjiu [An experimental study of the non-aspiration/aspiration distinction in Standard Chinese]. In Z.-J. Wu (Ed.), *Wuzongji Yuyinxue Lunwenji* [*Collection of Zhong-ji Wu's Linguistic Research Papers*]. Beijing: The Commercial Press, 31–65.

Streszczenie: Artykuł dotyczy postrzegania kontrastów dźwięczności w standardowym języku mandaryńskim przez rodowitych użytkowników języka polskiego. Autorka opisuje badanie empiryczne, któremu zostały poddani dorośli Polacy o biegłej znajomości mandaryńskiego oraz dorośli i dzieci, nieznający tego języka. Wyniki badania wskazują, że Polacy mają trudność z właściwym percypowaniem głosek zwarto-wybuchowych o krótkich wartościach VOT (0–20 ms), a czynniki istotne w postrzeganiu kontrastów dźwięczności to wiek danej osoby oraz jej doświadczenie w nauce mandaryńskiego. Osoby o biegłej znajomości języka konsekwentnie dzielą spółgłoski zwarto-wybuchowe na słabe (lenis) – /p t k/ oraz mocne (fortis) – /p^h t^h k^h/, a identyfikacja miejsca artykulacji danej spółgłoski jest dla nich stosunkowo łatwa. Natomiast u dorosłych nieznających mandaryńskiego tak silny efekt kategoryzacji nie występuje. Osoby te mają trudność z dokonaniem jednoznacznej oceny kategorii słyszanych spółgłosek, a odróżnianie spółgłosek dwuwargowych, zębowo-dziąsłowych i miękkopodniebiennych jest dla nich trudniejsze. Rozpoznawanie spółgłosek zwarto-wybuchowych jest również trudne dla najmłodszych Polaków, którzy mają tendencję do uznania spółgłosek słabych /p t k/ i mocnych /p^h t^h k^h/ za należące do tej samej kategorii spółgłosek mocnych.

Słowa kluczowe: Parametr VOT, percepcja, standardowy język mandaryński, kontrasty dźwięczności